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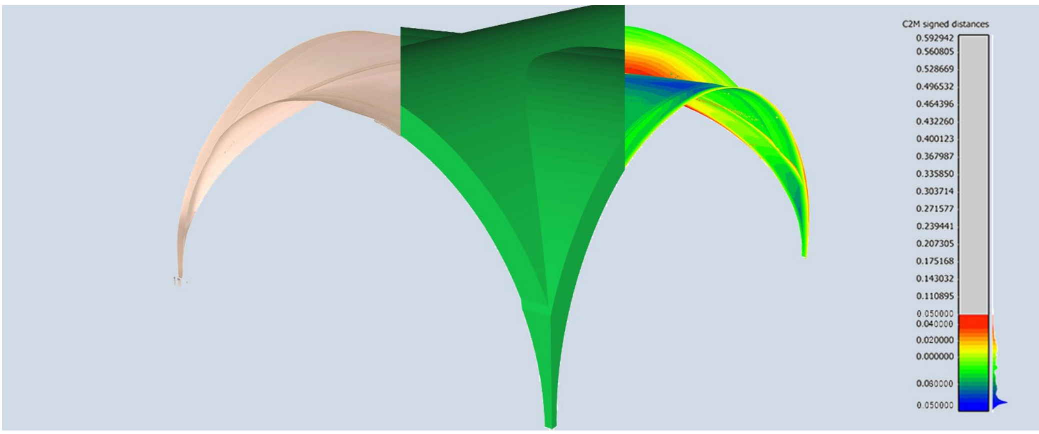
Modeling Historic Architecture: a Reflection on Representation in the BIM Environment

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Abstract

BIM modeling of architectural heritage raises important issues mainly related to the complexity of geometric shapes of architectural elements and the lack of specific libraries for the historical buildings. Therefore, reflection on how to model individual architectural components is necessary.
The choice of one modeling method rather than another and, at the same time, the acceptability or otherwise of the deviations between the model and the real element, depends on the objectives pursued and on the peculiarities of the building under study.
The paper deals with an experimentation concerning the use of different procedures for the modeling of vaulted ceilings, with the aim of evaluating the benefits and disadvantages of each procedure, also taking into consideration the different deviation values obtained.

Keywords
HBIM, Three-Dimensional Modeling, Deviation, Historical Buildings



Modeling of a cross vault: point cloud on the left, three-dimensional model in the center, deviation evaluation on the right. Graphic elaboration by the authors.

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Introduction

Three-dimensional modeling of architectural heritage is an important tool for understanding historical and artistic values and, at the same time, for documentation and enhancement. In this context, the Historic Building Information Modeling (HBIM) adds to the traditional advantages offered by graphic representation, the benefits of an information base bidirectionally connected to smart objects representing the architectural components of the building. Hence the growing interest among those involved in architectural heritage towards a modeling, the BIM one, developed specifically for architecture.
However, in the face of numerous advantages, extending a procedure designed for new construction to existing buildings raises specific issues, mainly related to the complexity of the geometric shapes of the elements of historic architecture.
The lack of BIM libraries for historic buildings, on the one hand, and the irregularity of forms, on the other, mean that modeling architectural heritage can be a rather onerous activity, which requires specific considerations and evaluations.
Based on the comparison of different procedures, in terms of deviation between model and real object and time taken, the paper proposes a reflection on BIM modeling of historical heritage. In particular, the paper presents an experiment concerning the creation of vaults in a BIM environment through the use of different procedures developed with different software (Acca Edificius and Autodesk Revit) (fig. 1).

3D models for historical buildings

The architectural asset, the outcome of processes of modification and stratification that have occurred over time, is an expression of the building cultures that have succeeded one another over the centuries. It is configured as a complex system, a synthesis of spaces, volumes, surfaces, materials, lighting, construction equipment, historical phases, etc., to which is added a close connection with the context, an element that characterizes the field of architecture.
The starting point for the study of architectural heritage is archival-documentary research and the survey campaign. Critical analysis of the data thus acquired leads to the creation of the restitutive model. Three-dimensional modeling can be likened to Visual Computing, a data processing technique based on their visual representation, through which information can be derived and new knowledge created [Brusaporci 2015].
During the modeling process, the architectural asset is examined in its constituent aspects, which are then translated into three-dimensional digital elements. By modeling the building, the scholar analyzes its architectural, spatial, technical, and material characteristics, but also aspects related to constructional events and the modifications that have occurred over time, thus coming to grasp all the values it carries.
The 3D model should therefore be understood as a visual tool for the study and analysis of architectural features and, at the same time, for the verification of hypotheses and research conducted on architectural heritage. The model structured in this way becomes a tool for the historical-critical analysis of the building, constituting the access interface to the knowledge of the asset.

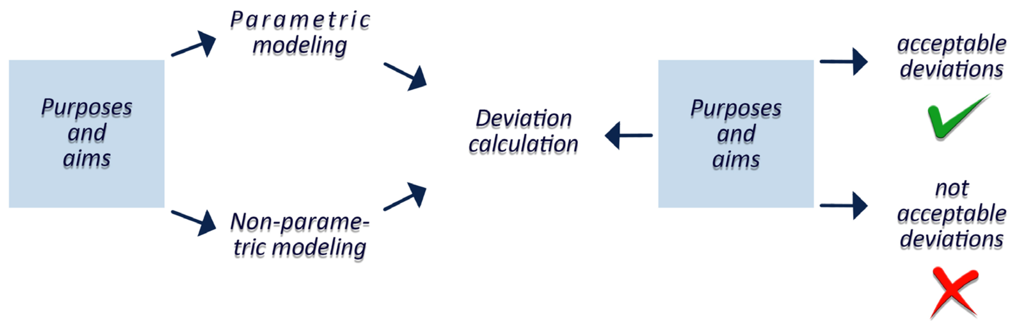


Fig. 1. HBIM element modeling procedure scheme. Graphic elaboration by the authors.

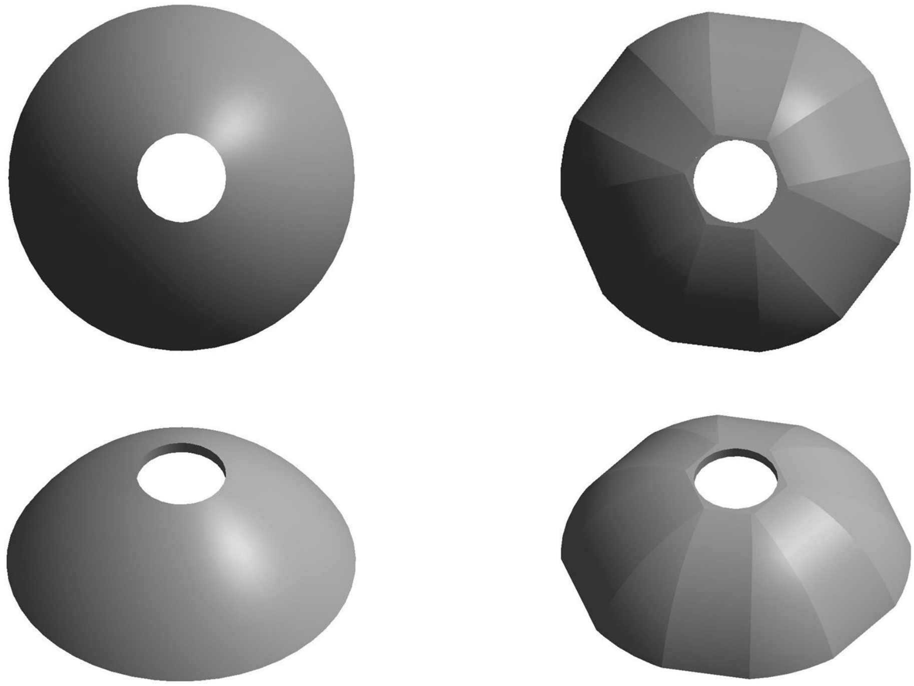


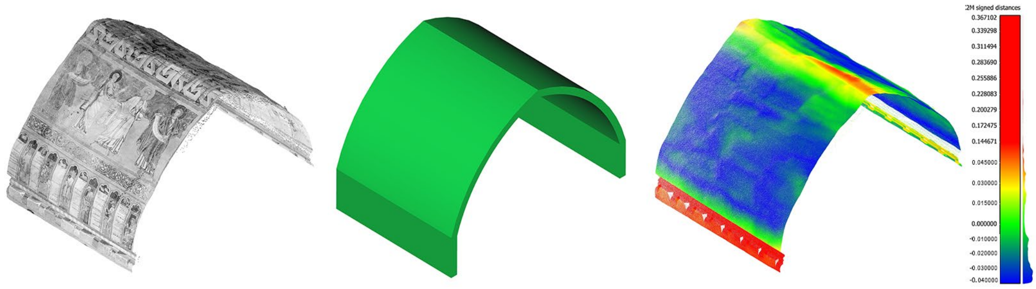
Fig. 2. Dome of the Baptistery of Santa Maria extra Moenia of Antrodoco (RI). Comparison between the simplified parametric model with low level of development and the more detailed non-parametric model with higher level of development. Graphic elaboration by the authors.

Among the different types of models for architectural heritage, BIM ones pose specific issues. With regard to modeling, in particular, BIM poses the problem of how to reconcile the standardization of architectural elements, proper to BIM, with that which represents the feature of historical heritage, namely its uniqueness [Bianchini 2017]. This uniqueness, in fact, due to the craftsmanship of the manufacturing process and to the transformations undergone over time, makes the historical artefact difficult to submit to a logic based on standardization (fig. 2).
Added to this criticality is the insufficiency of the current parametric libraries, the foundation of the standardised logic of BIM. The libraries prepared by BIM software, in fact, thought up for the design of new buildings, present obvious shortcomings for the parametric representation of heritage architectural components, such as vaults, arches, highly irregular masonry, etc.
Compared to new buildings, the geometric modeling of historical architectures, while on the one hand requires more effort, on the other requires a critical assessment of the most suitable procedure to adopt, in relation to the purposes of the model and the characteristics of the building.
One way forward is to relate the architectural elements of the building to typified objects, losing the peculiarities and dissimilarities of a real historical object compared to one belonging to a library. The accuracy of the survey data is set aside in favour of the use of standardised parametric families, which allow a significant reduction in modelling time.
The other possibility, on the other hand, in accordance with the historicist approach, implies a greater adherence to the survey data by analysing and, therefore, modelling the architectural element of the specific building with the anomalies that distinguish it. This respect for the historical and geometric uniqueness of the building leads, in fact, to the scaling down of the typed library approach, with a consequent lengthening of the modelling phase.
The two different modelling strategies for historical architecture thus lead to significantly different deviations between the model and the point cloud, against a greater or lesser speed in the realization of the model [Brumana 2018] (fig. 3, 4).

HBIM modeling strategies and procedures

As mentioned above, among the main criticalities encountered in the use of BIM software for heritage, there is the general absence of libraries of predefined parametric objects suitable for existing and historical buildings. Existing libraries, in fact, often consist exclusively of

Fig. 3. Barrel vault of the Oratory of San Pellegrino in Bominaco (AQ): point clouds from the survey on the left, three-dimensional parametric model in the center and calculation of the deviation to the right. Graphic elaboration by the authors.



objects based on standardized logics and present obvious deficiencies with respect to the parametric representation of the heritage architectural components. Among these, stands out in particular the case of vaulted ceilings, which constitutes the most complex and difficult element to represent in a BIM environment. In fact, these elements are not only absent in the current libraries, but in general they are not even included in today's BIM software families. Therefore, their modeling requires specific considerations regarding, firstly, the selection of a related family in which they can be inserted and, secondly, the choice of the best modeling procedure, according to the purposes and aims.

With regard to this, some of the existing modeling software is being updated and constantly implemented with the aim of expanding these libraries and allowing for an easier and quicker representation of the heritage. Among these is the ACCA Edificius software which in the latest update presents a specific section for historic buildings in its parametric library, called 'Heritage BIM', also containing the vaults family.

Therefore, the present experimentation was dedicated to the modeling of vaults through the use of different procedures and software, in order to evaluate the benefits or disadvantages of each methodology, taking into account also the variation of the deviations deriving from the choice of a modeling method rather than another.

Thus, three different vaults as case studies were selected: a barrel vault with a lancet arch; a round arch cross vault; and a segmental arch dome [1]. Two models were therefore created for each vault: a simplified and parametric one, created with the ACCA Edificius software, through the use of the new libraries made available for the built heritage; a more realistic one, with a high level of detail, modeled within Autodesk Revit software, created as a local model.

At the end of the modeling phase, the two models of each vault (the parametric and the local one) were compared with the reference point cloud to evaluate its deviations [Meyer 2022; Wang 2022]. From the conducted experimentation it emerged that on average for the local models, the deviation in most of the surface of the vaults is less than 3 cm, and the maximum error is 4 cm; instead, as regards the parametric models, the deviation of with respect to the cloud is greater, and is mostly higher than 4 cm, with a maximum error of 6 cm (fig. 5, 6).

In particular, from parametric modeling derives more or less abstract and simplified models which can deviate quite a bit from the real object at the end of the modeling phase. However, this is contrasted by the benefits deriving from the use of parametric elements loaded from libraries which lead to a more efficient and, in the long term, advantageous workflow, considering the speed of modification of the model and the correct semantization of the same. Local modeling, on the other hand, is characterized by greater freedom and the possi-

Fig. 4. Cross vault of Palazzo Camponeschi (AQ): point clouds from the survey on the left, three-dimensional parametric model in the center and calculation of the deviation to the right. Graphic elaboration by the authors.



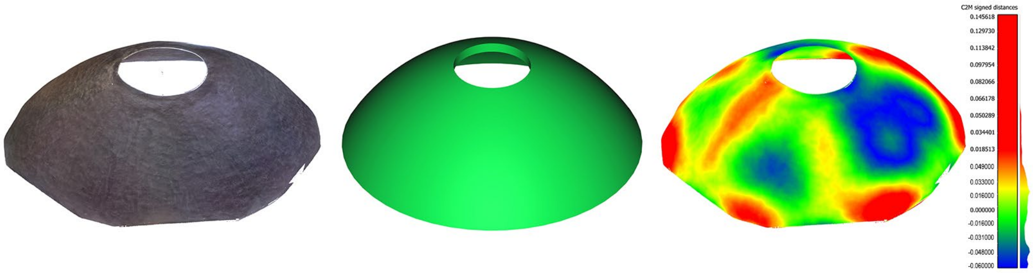


Fig. 5. Dome of the Baptistery of Santa Maria extra Moenia of Antrodoco (RI): point clouds from the survey on the left, three-dimensional parametric model in the center and calculation of the deviation to the right. Graphic elaboration by the authors.

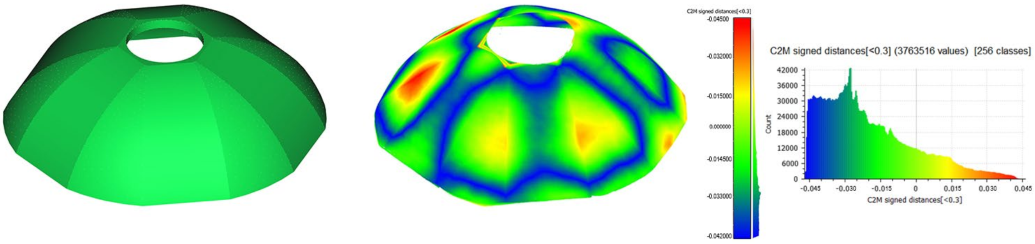


Fig. 6. Dome of the Baptistery of Santa Maria extra Moenia of Antrodoco (RI): detailed three-dimensional model on the left and calculation of the deviation to the right. Graphic elaboration by the authors.

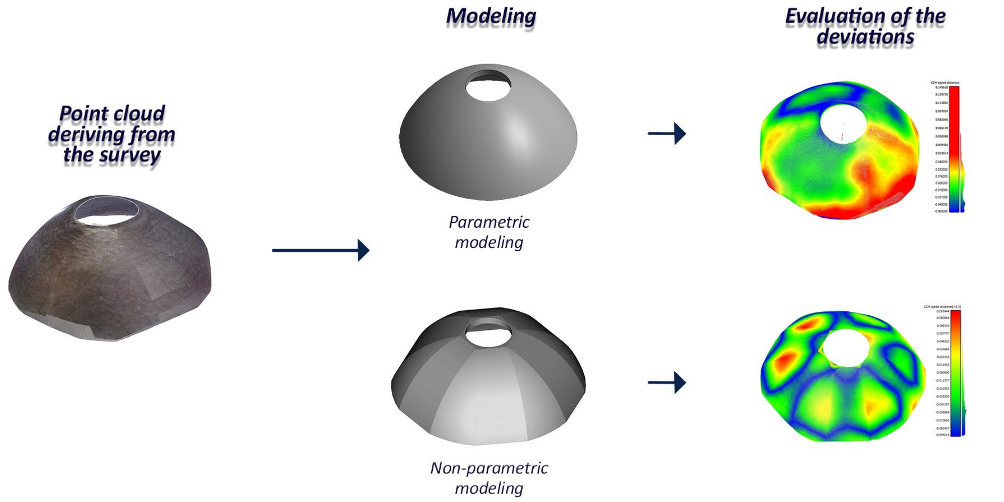


Fig. 7. Outcome of the evaluation of the deviations of the two distinct modeling procedures: parametric modeling, above, and local modeling, below. Choosing whether to use a modeling method or otherwise, and accept, or not, the resulting deviations depends solely on the purposes and uses of the model. Graphic elaboration by the authors.

bility of creating models that are more in accordance with the specificities of the elements being modelled. However, these models are unrelated to the logic of efficiency, typical of BIM, linked to the standardization and reuse of three-dimensional elements. In fact, local models are non-parametric models, existing only within the single project in which they are created, and therefore they are neither shareable nor reusable.

The choice of one modeling method over another and, at the same time, the acceptability or otherwise of certain deviation values, depends on the purposes and characteristics of the building under investigation. Finally, if necessary, the methods can be integrated with each other, in order to include the advantages of both approaches (fig. 7).

Conclusion

Historic BIM is understood as a multidisciplinary system consisting in the creation of intelligent objects, semantically referable to the constructive system, parameterized on the data deriving from the survey.

As previously highlighted, the extension of the BIM procedure to the existing assets is still characterized by open issues which require specific considerations and attention.

The model, in fact, derives from a process of evaluation and critical restitution in which the level of development and the consequent difficulties in the construction and informatization phase derive both from the purposes of the modeler and from the specific charac-

teristics and needs of the historical building, which differ from those of the new buildings for which BIM was born. On the basis of these, in fact, will be defined the characteristics of the model and of the architectural elements that compose it (level of development, degree of parameterization and, consequently, of simplification and approximation), the best procedure for modeling (by creating parametric BIM families, local models, parametric surfaces, NURBS surfaces or meshes) and the acceptability, or not, of the deviation from the point cloud. For the modeling of the geometric aspects, therefore, on the basis of critical evaluations, one will choose between a detailed and accurate modeling that respects the specific characteristics and peculiarities of the architectural element, or a simplified representation attributable to standardized and typified objects, typical of the BIM logic.

Notes

[1] The barrel vault is from the Oratory of San Pellegrino in Bominaco (AQ), the cross vault belongs to Palazzo Camponeschi in L'Aquila, while the dome is from the Baptistery of Santa Maria extra Moenia in Antrodoco (RI).

Credits

Although the contribution was conceived jointly, Maiezza is author of 'Introduction' and '3D models for historical buildings'; Tata of 'HBIM modeling strategies and procedures' and 'Conclusion'.

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